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IWM-EC 2014 - INTERNATIONAL WORKSHOP ON MULTI FACETS OF EOS AND CLUSTERING (ISSN: 2100-014X)

Citation for the published paper:
Fernandez-Garcia, J. ; Cubero, M. ; Acosta, L. et al. (2014) "Li-11 structural information from inclusive break-up measurements". IWM-EC 2014 - INTERNATIONAL WORKSHOP ON MULTI FACETS OF EOS AND CLUSTERING, vol. 88

http://dx.doi.org/10.1051/epjconf/20158801003

(article starts on next page)

EPJ Web of Conferences **88**, 01003 (2015)
DOI: 10.1051/epjconf/20158801003

^{11}Li structural information from inclusive break-up measurements

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Abstract

Structure information of ^{11}Li halo nucleus has been obtained from the inclusive break-up measurements of the ^{11}Li+^{208}Pb reactions at energies around the Coulomb barrier (E_{lab} = 24.3 and 29.8 MeV). The effective break-up energy and the slope of $B(E1)$ distribution close to the threshold have been extracted from the experimental data.

The ^{11}Li halo nucleus can be understood as a ^{9}Li core and two weakly bound neutrons. Due to its loosely bound nature, this nucleus will be easily polarizable in presence of a strong Coulomb field, such as that produced by a heavy target like ^{208}Pb. This leads to a significant deviation of the elastic cross section with respect to the Rutherford formula as well as a high break-up probability [1, 2].

The break-up cross sections can be conveniently analyzed in terms of the so-called *reduced break-up probability*. This quantity is defined as the usual break-up probability (ratio between break-up yield and total yield), divided by some kinematical factors [2] and expressed in terms of the collision time, that is:

$$P_r(t) = P_{BU}(E1,\theta)\frac{9t^2(\hbar v)^3 a_0}{16\pi^2(Z_A e)^2\sin(\theta/2)} = \int \mathrm{d}\varepsilon \frac{\mathrm{d}B(E1)}{\mathrm{d}\varepsilon}\varepsilon e^{-t\varepsilon}t^2, \quad (1)$$

where the collision time, t, is given by the equation,

$$t = \frac{a_0}{\hbar v}(\pi + \frac{2}{\sin(\theta/2)}). \quad (2)$$

This new variable, t, is related with the time taken by the projectile to cross approximately the distance of closest approach, where it can be excited by the electric field of the target.

For large collision times, the *reduced break-up probability* is determined by excitation energies close to the break-up threshold. Therefore, the integral factor of the eq. (1) can be approximated by the following expression,

$$\varepsilon\frac{\mathrm{d}B(E1)}{\mathrm{d}\varepsilon} \simeq b(\varepsilon - \varepsilon_b), \quad (3)$$

where ε_b represents the effective break-up threshold, while the parameter b is associated with the slope of the $B(E1)$ distribution at low excitation energies. The approximation of eq. (3) allows to evaluate analytically the integral appearing in eq. (1), leading to the following expression for the *reduced break-up probability*,

$$P_r(t) \approx b e^{-\varepsilon_b t}. \quad (4)$$

A more detailed discussion of this new quantity can be found in ref. [2].

On the left side of fig. 1, we plot the experimental *reduced break-up probability* calculated with the data from the present experiment, at the two measured energies. It can be seen that the scaling property predicted by eq. (4) is well reproduced by the data.

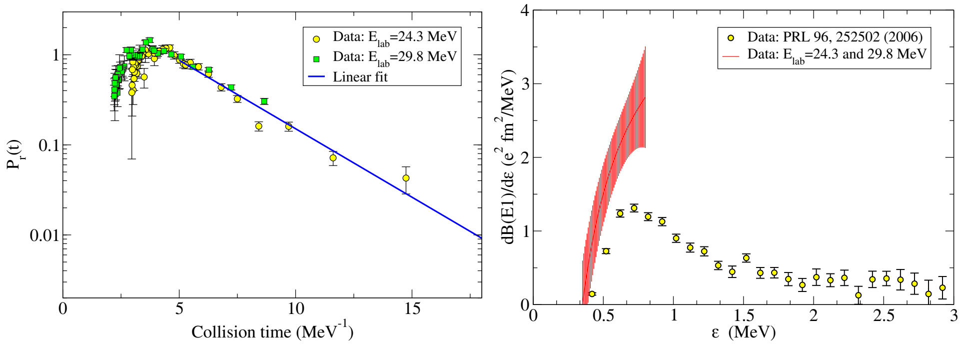

Figure 1: *Reduced break-up probability* as a function of the collision time (on left). $B(E1)$ distributions of ^{11}Li as a function of the excitation energy (on right).

A linear fit of the experimental data for collision times higher than 5 MeV^{-1} (see blue line in fig. 1) gives a ε_b=0.35±0.04 MeV, which is in a good agreement with the accepted value for the measured separation energy of ^{11}Li [3]. Moreover, such linear fit gives the value of the parameter b=5.0±0.3 e^{2}fm^2/MeV. From these results, the behavior of the $B(E1)$ distribution at excitation energies close to the break-up threshold obtained by eq. (3) (see red area in fig. 1) has been compared with the one obtained in ref. [4]. The $B(E1)$ distribution at low excitation energies extracted from the present experimental data suggests a larger E1 strength as compared to the values extracted from Coulomb dissociation experiments [4].

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